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PREDICTION OF RESIDUAL CANOPY COVER FOR WHITE PINE IN CENTRAL ONTARIO

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INTRODUCTION

Prediction of residual canopy cover can enable forest managers to better prescribe the percent of canopy cover to be cut or remain in a forest stand. This planning tool may provide economic benefits by reducing planting costs, promoting natural regeneration, and protecting nontimber forest values, such as wildlife habitat. As an example of the latter, to sustain suitable habitat and populations, desirable residual canopy covers are 60 percent for deer (Odoecileus virginianus [Zimm.]) management, and 70 percent surrounding red-shouldered hawk (Buteo lineatus elegans) nests (Voigt 1990, Bellhouse and Naylor 1993).

In the white pine (*Pinus strobus* L.) working group, a larger area of central Ontario was harvested in 1990–91 with the shelterwood system than with the clear-cut system (e.g., 3 565 ha versus 1 056 ha) (Pinto 1992). Application of the shelterwood system provides a partial canopy that encourages regeneration and early growth of the desired species, and restricts competing vegetation. It may involve several types of cuts: preparatory, regeneration (seeding), and removal (Leak and Tubbs 1983, Chapeskie et al. 1989).

This project focuses upon the regeneration cut, which induces the stand to naturally regenerate white pine. This cut should be timed to coincide with the forecast of an abundant white pine seed crop. A target of 50 percent canopy cover, after the seeding cut, will provide a good environment for germination and growth of white pine seedlings. It will also help to reduce white pine weevil (*Pissodes strobi* [Peck]) and blister rust (*Cronastium ribicola* [Fischer]) damage[1] and control competition from undesirable species (Pinto 1992). To reach the target canopy cover, poor quality white pine and other species will be removed first from the overstory left after the preparatory cut. Ideally, only healthy and vigorous white pine should remain to provide seed and shelter, and to increase in size and value.

The goal of this project is to examine natural canopy cover and to then use the field data to produce guides for managing white pine stands in central Ontario. This will allow managers and tree markers to quickly calculate both the percent canopy cover of a stand and the desirable percent residual canopy cover.

METHODS AND MATERIALS

Fourteen uncut stands were selected in the North Bay and Temagami districts of the Central Region. All had more than 30 percent of their basal area composed of white pine. Stand characteristics, determined from the Forest Resource Inventory (FRI) database, included 30–100 white pine, stocking of 30–80 trees per hectare, and an age of 20–141+ years.

Within each stand (minimum 8 ha), five prism plots were randomly located at least 30 m apart. A 2 m^2/ha basal area factor prism (metric BAF-2 prism) was used to determine the trees in the plot, and the basal area of the stand. Data was collected for individual trees having a minimum

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[1] Szuba, K.; Pinto, F. 1991. Natural history of the white pine weevil and strategies to decrease its damage to conifers in Ontario. Ont. Min. Nat. Resour., Central Ontario Forest Technology Development Unit, North Bay, ON. Unpublished report.

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10-cm diameter at breast height (DBH). Percent canopy closure was estimated with an optical densiometer (moose horn) at five points in each plot (center and four cardinal points). The trees were organized into three species groups: white pine (*Pinus strobus* L.); other conifers (red pine [*Pinus resinosa* Ait.], jack pine [*Pinus banksiana* Lamb.], balsam fir [*Abies balsamea* (L.) Mill.], black spruce [*Picea marina* (Mill.) B.S.P.], and tamarack [*Larix laricina* (DuRoi) K. Koch]); and hardwoods (white birch [*Betula papyrifera* Marsh.], hard and soft maples [*Acer* spp.], red oak [*Quercus rubra* L.], and poplar [*Populus tremuloides* Michx]). They were then placed into 2-cm diameter classes for data analysis. Crown area per tree was calculated, by diameter class, from individual crown diameter measurements using the formula for the area of a circle (TTr^2). Further details of this methodology are reported elsewhere.[2]

RESULTS AND DISCUSSION

The tree data were used to explore various relationships between tree growth and stand parameters associated with canopy cover: namely, basal area and canopy cover, tree diameter and crown diameter, tree diameter and crown area, and stand age and canopy cover. The most consistent relationship for this data set occurred between diameter class and crown area. Other relationships are presented by Bentley.[3]

For each species group a model that related crown area to diameter class was developed. For the white pine and other conifer groups, the best fit relationship was produced with the logarithmic power function ($y = a \times x^b$) for nonlinear regression (power regression). Linear regression with one extra data point (0 cm = 0 m^2) was the best fit for the hardwood species group. These equations are:

White pine
Crown area = $0.429 \times dbh^{1.253}$ ($r^2 = .95$)

Other conifers
Crown area = $0.123 \times dbh^{1.540}$ ($r^2 = .91$)

Hardwoods
Crown area = $5.608+0.850 \times dbh$ ($r^2 = .75$)

The relationship between predicted values and observed values was determined by regressing predicted crown area (PCA) values (from the above equations for each diameter class) on observed crown area (OCA) values (from sample data). The equations suggest that the models are reliable predictors of crown area.

PCA = $9.202+0.837 \times OCA$ ($r^2 = 0.81$) for white pine, PCA = $5.409+0.776 \times OCA$ ($r^2 = 0.86$) for other conifers, and PCA = $8.149+0.732 \times OCA$ ($r^2 = 0.68$) for hardwoods.

The predicted crown area equations were used to construct Table 1, which shows percent canopy cover for each tree counted in a metric BAF-2 prism plot:

> Percent canopy cover = (crown area per tree [m^2]/ 10 000[m^2/ha]) x number of trees per hectare x 100

for each diameter class and species group. Table 1 is designed for use in the field. Step one involves summarizing data by species group into diameter classes. Next, using this tally, percent canopy cover is read from Table 1 in the appropriate diameter class and multiplied by the tree count. To arrive at total percent canopy cover, simply sum the percent canopy cover figures in each diameter class. This method was applied successfully by Leak and Tubbs (1983) to estimate residual percent crown cover in shelterwood cuts, for dominant forest trees in New England, using an imperial BAF-10 prism. When a plot is sampled using other than a metric BAF-2 prism, the tree count per plot must be converted to trees per hectare. This can be accomplished by using the following formula and then determining the percent canopy cover from Table 2.

> Number of trees per hectare = (metric prism's BAF/ [TTr^2/10 000]) x number of trees tallied, where r = radius of the diameter class in cm.

Table 2 shows percent canopy cover per tree per hectare by species group and by diameter class:

> Percent canopy cover per tree = (crown area per tree in m^2/10 000 m^2 per hectare) x 100, or simplified = crown area per tree/100.

For example, in Plot 20, the tree tally was:

(1)	(2)		(3)	(4)		(5)	
Diameter class (cm)	Species group tally Pw	OC	Stems per hectare	% canopy cover (from Table 1) Pw	OC	% canopy cover (from Table 2) Pw	OC
24	1		44.24	10.18	0	10.18	
26	1		37.69	9.59	0	9.42	
30	1		28.31	8.62	0	8.49	
32	3		24.88	24.63	0	24.63	
34	1	1	22.04	7.85	6.21	7.93	6.17
44	2		13.16	12.94	0	12.90	
46	1		12.04	6.26	0	6.26	
Total	10	1		80.07	6.21	79.81	6.17
				=86.28%		=85.98%	

Using Table 1, white pine accounts for 80.07 percent of the canopy cover and the other conifers account for 6.21 percent of the crown cover, for a total of 86.28 percent

[2]Bentley, C.V. 1994. Prediction of residual canopy cover for white pine in central Ontario. Nat. Resour. Can., Canadian Forest Service–Sault Ste. Marie, ON. NODA Project No. 4041. Unpublished report. 17 p.

[3]Ibid.

Table 1. Percent canopy cover, by diameter class and species group, for use with tree counts from metric BAF-2 prism plots.

Diameter class (cm)	Species group: White pine Crown area = 0.429 x $DBH^{1.253}$ (r^2 = .95)		Species group: Other conifers Crown area = 0.123 x $DBH^{1.54}$ (r^2 = .91)		Species group: Hardwoods Crown area = 5.608 + 0.850 x DBH (r^2 = .75)	
	Crown area per tree (m^2)	Percent canopy cover per tree tallied	Crown area per tree (m^2)	Percent canopy cover per tree tallied	Crown area per tree (m^2)	Percent canopy cover per tree tallied
10	7.69	19.58	4.28	10.91	14.11	35.93
12	9.66	17.09	5.67	10.03	15.81	27.95
14	11.72	15.23	7.19	9.34	17.51	22.75
16	13.86	13.78	8.83	8.79	19.21	19.11
18	16.06	12.62	10.59	8.32	20.91	16.43
20	18.32	11.67	12.46	7.93	22.61	14.39
22	20.65	10.86	14.43	7.59	24.31	12.79
24	23.03	10.18	16.49	7.29	26.01	11.50
26	25.46	9.59	18.66	7.03	27.71	10.44
28	27.93	9.07	20.91	6.79	29.41	9.55
30	30.45	8.62	23.26	6.58	31.11	8.80
32	33.02	8.21	25.69	6.39	32.81	8.16
34	35.62	7.85	28.20	6.21	34.51	7.60
36	38.27	7.52	30.80	6.05	36.21	7.11
38	40.95	7.22	33.47	5.90	37.91	6.69
40	43.67	6.95	36.23	5.77	39.61	6.30
42	46.42	6.70	39.05	5.64	41.31	5.96
44	49.21	6.47	41.95	5.52	43.01	5.66
46	52.03	6.26	44.93	5.41	44.71	5.38
48	54.87	6.06	47.97	5.30	46.41	5.13
50	57.75	5.88	51.08	5.20	48.11	4.90
52	60.66	5.71	54.26	5.11	49.81	4.69
54	63.60	5.55	57.51	5.02	51.51	4.50
56	66.56	5.41	60.82	4.94	53.21	4.32
58	69.56	5.27	64.20	4.86	54.91	4.16
60	72.57	5.13	67.64	4.78	56.61	4.00
62	75.62	5.01	71.15	4.71	58.31	3.86
64	78.69	4.89	74.71	4.64	60.01	3.73
66	81.78	4.78	78.34	4.58	61.71	3.61
68	84.90	4.68	82.02	4.52	63.41	3.49
70	88.04	4.58	85.77	4.46	65.11	3.38
72	91.20	4.48	89.57	4.40	66.81	3.28
74	94.37	4.39	93.43	4.34	68.51	3.19
76	97.59	4.30	97.35	4.29	70.21	3.10
78	100.82	4.22	101.32	4.24	71.91	3.01
80	104.07	4.14	105.35	4.19	73.61	2.93
82	107.34	4.06	109.44	4.14	75.31	2.85
84	110.63	3.99	113.57	4.10	77.01	2.78
86	113.94	3.92	117.76	4.05	78.71	2.71
88	117.27	3.86	122.01	4.01	80.41	2.64
90	120.61	3.79	126.31	3.97	82.11	2.58
92	123.98	3.73	130.65	3.93	83.81	2.52
94	127.37	3.67	135.05	3.89	85.51	2.46
96	130.77	3.61	139.51	3.85	87.21	2.41
98	134.19	3.56	144.01	3.82	88.91	2.36
100	137.63	3.50	148.56	3.78	90.61	2.31

Table 2. Percent canopy cover per tree, by diameter class and species group, for use with stems per hectare data.

Diameter class (cm)	Species group: White pine Crown area = 0.429 x DBH$^{1.253}$ (r^2 = .95)		Species group: Other conifers Crown area = 0.123 x DBH$^{1.54}$ (r^2 = .91)		Species group: Hardwoods Crown area = 5.608 + 0.850 x DBH (r^2 = .75)	
	Crown area per tree (m^2)	Percent canopy cover per tree per hectare	Crown area per tree (m^2)	Percent canopy cover per tree per hectare	Crown area per tree (m^2)	Percent canopy cover per tree per hectare
10	7.69	0.08	4.28	0.04	14.11	0.14
12	9.66	0.10	5.67	0.06	15.81	0.16
14	11.72	0.12	7.19	0.07	17.51	0.18
16	13.86	0.14	8.83	0.09	19.21	0.19
18	16.06	0.16	10.59	0.11	20.91	0.21
20	18.32	0.18	12.46	0.12	22.61	0.23
22	20.65	0.21	14.43	0.14	24.31	0.24
24	23.03	0.23	16.49	0.16	26.01	0.26
26	25.46	0.25	18.66	0.19	27.71	0.28
28	27.93	0.28	20.91	0.21	29.41	0.29
30	30.45	0.30	23.26	0.23	31.11	0.31
32	33.02	0.33	25.69	0.26	32.81	0.33
34	35.62	0.36	28.20	0.28	34.51	0.35
36	38.27	0.38	30.80	0.31	36.21	0.36
38	40.95	0.41	33.47	0.33	37.91	0.38
40	43.67	0.44	36.23	0.36	39.61	0.40
42	46.42	0.46	39.05	0.39	41.31	0.41
44	49.21	0.49	41.95	0.42	43.01	0.43
46	52.03	0.52	44.93	0.45	44.71	0.45
48	54.87	0.55	47.97	0.48	46.41	0.46
50	57.75	0.58	51.08	0.51	48.11	0.48
52	60.66	0.61	54.26	0.54	49.81	0.50
54	63.60	0.64	57.51	0.58	51.51	0.52
56	66.56	0.67	60.82	0.61	53.21	0.53
58	69.56	0.70	64.20	0.64	54.91	0.55
60	72.57	0.73	67.64	0.68	56.61	0.57
62	75.62	0.76	71.15	0.71	58.31	0.58
64	78.69	0.79	74.71	0.75	60.01	0.60
66	81.78	0.82	78.34	0.78	61.71	0.62
68	84.90	0.85	82.02	0.82	63.41	0.63
70	88.04	0.88	85.77	0.86	65.11	0.65
72	91.20	0.91	89.57	0.90	66.81	0.67
74	94.37	0.94	93.43	0.93	68.51	0.69
76	97.59	0.98	97.35	0.97	70.21	0.70
78	100.82	1.01	101.32	1.01	71.91	0.72
80	104.07	1.04	105.35	1.05	73.61	0.74
82	107.34	1.07	109.44	1.09	75.31	0.75
84	110.63	1.11	113.57	1.14	77.01	0.77
86	113.94	1.14	117.76	1.18	78.71	0.79
88	117.27	1.17	122.01	1.22	80.41	0.80
90	120.61	1.21	126.31	1.26	82.11	0.82
92	123.98	1.24	130.65	1.31	83.81	0.84
94	127.37	1.27	135.05	1.35	85.51	0.86
96	130.77	1.31	139.51	1.40	87.21	0.87
98	134.19	1.34	144.01	1.44	88.91	0.89
100	137.63	1.38	148.56	1.49	90.61	0.91

canopy cover in this plot on a per hectare basis. Alternatively, trees per plot can be converted to trees per hectare for each species group and diameter class. From Table 2, take the value at the appropriate diameter class and multiply by the number of stems per hectare. This yields the values in Column 5, for a total of 85.98 percent canopy cover per hectare (79.81 percent for white pine and 6.17 percent for other conifers). To use this model, the desired residual canopy cover of 50 percent could be attained if 36 percent of the existing 86 percent canopy cover is removed. Since white pine is the desired species, the maximum number of white pine stems are retained. Other conifers and hardwood species, as well as trees for spacing requirements and ones in decline or poor health, are suitable for removal. The process of selecting trees for removal to meet the target residual canopy cover must include spacing in the stand, percent canopy cover available, and residual target. It must also consider tree species, form, health, defect, vigor, seed potential, and response to release. Small diameter trees should also be considered in estimating the residual canopy cover. As shown in Table 1, small trees contribute a disproportionate share of the percent canopy cover (Leak and Tubbs 1983) since they have wider crowns per centimeter of diameter than do larger trees (Godman and Tubbs 1973).

The tables can also be used for estimating the appropriate residual basal area for a shelterwood cut, so as to attain the desired percent canopy cover (Leak and Tubbs 1983). For example, with a plot having six white pines in the 60-cm diameter class, Table 1 shows that these trees represent 30.78 percent of the canopy cover (5.13 percent x six trees), and 12 m^2/ha of basal area (six trees x BAF-2 prism).

RECOMMENDATIONS AND CONCLUSIONS

Natural canopy cover was examined in white pine stands for the purpose of providing guides for estimating percent canopy cover. Of the relationships tested, the most practical and reliable indicator of crown area was diameter.

From this project and others mentioned earlier, basal area was a poor indicator of percent canopy cover, since the basal area/crown area relationship varies. If possible, moose horn readings should be validated with a visual canopy cover estimate or other method of calibration for the stand.

In the white pine working group, 50 percent residual canopy cover is desirable for natural regeneration (Pinto 1992). The model developed for each species group was used to produce tables of percent canopy cover for field use. Once forest managers have selected the residual canopy cover for a stand, use of the tables will enable workers to mark stands to these specifications. Tables are for use with plot data (tree count from stand tallies or stems per hectare). To apply them, foresters must determine the percent canopy cover for a plot from the appropriate table, consider the desired residual canopy cover, and decide which stems to remove in the shelterwood cut. Consideration must also be given to individual canopy cover, species, spacing, health, vigor, defect, seed potential, and diameter.

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